

Gravitational and Space Research

USB Triggering of Video Recording in Sub-orbital Experiments

Monish Lokhande, Steven H. Collicott*

School of Aeronautics and Astronautics, Purdue University

Abstract

Successful sub-orbital flight operations of a novel method for autonomously controlling GoPro cameras in microgravity, without any additional mechanical device, are described. The method employs the use of GoPro Labs software to control the power and recording functions of a camera via its USB port and integrates the camera and control with the Integrated Payload Controller (IPC) of the Blue Origin New Shepard crew capsule or with microprocessor control of cameras in Virgin Galactic's VSS Unity. Control of four GoPro Hero-10 cameras on a single power port on the IPC is achieved. The method operated successfully on the Blue Origin New Shepard NS-24 suborbital flight, recording data in the experiment and demonstrating reliable start- and stop-recording functions during the flight. The authors also operated four GoPro Hero-11 cameras via USB port recording control on Virgin Galactic's June 8, 2024 flight. Hardware specifications for the experimental setup and the ability to operate after extended periods of inactivity are discussed.

Keywords

sub-orbital • experiment design • data acquisition

Introduction

High-definition digital video cameras are now common in a consumer, that is, non-scientific, market. Sports activities, automotive safety, and other needs have created the availability of low-cost, compact digital video cameras with high resolution (to date, up to the 8K format), 30, 60, or even more frames per second, self-contained with power and data storage, and image stabilization. A commercial modification of these cameras provides the nearly century-old traditional “C-mount” for lenses, and this allows a researcher to choose from a wide variety of interchangeable lenses to optimize the spatial performance of their video data acquisition.

The consumer market cameras have typically required a mechanical button to be pressed – generally by the consumer's finger – although some also have a voice activation option. Automated spaceflight experiments benefit from automated control of the camera, most specifically the starting and ending of the recording of video. It is possible to construct an electro-mechanical button-pusher, although this then adds more actions to control and reduces the volume, mass, and power available to the primary purpose of the experiment. It also adds another source of possible electromagnetic interference acting on other experiments or the vehicle, or for the vehicle or other experiments to act on. A simpler control of these cameras allows the numerous

benefits of the consumer high-definition video cameras to be applied to an experiment design. Demonstration of such a method for starting and ending video recording activated four days after handing off the experiment to the flight provider, with the experiment sitting unpowered those four days until a few minutes before lift-off is described. This method makes use of the USB power supply connection to the camera with the camera battery still present. The method described below relies on a little-known option created by the camera manufacturer that has now been proven to work well in commercial re-usable sub-orbital spaceflight.

Method

The purpose of the cameras in the sub-orbital flight experiment (GoPro Hero-10 in “Two-dimensional Slosh” and GoPro Hero-11 in “Rotational Slosh”) is to record the motion of a liquid-gas contact line caused by the (planned) oscillations of the fluid vessels (Lokhande, 2023). The aim is to record the fluid motion for the entire Blue Origin suborbital flight, from liftoff to landing and from boost to re-entry on Virgin Galactic. The use of an electromechanical device, mimicking a human finger, to activate the record button on the cameras to start and stop the recording

[†] Corresponding author: Steven H. Collicott
E-mail: collicott@purdue.edu

was planned initially. This device was prone to failure and was thus replaced by the USB trigger control for the GoPro cameras. The USB control not only reduced the complexity of the experiment hardware and operations but also reduced the possibility of mechanical failure and camera damage. The final setup for camera is shown in FIG. 1.

The camera USB trigger software used in the experimental setup is developed by GoPro as an open-source project called "GoPro Labs." The GoPro Labs project provides various additional functions for the camera, one of which is using the USB power as a recording trigger. The software is compatible with numerous GoPro camera models; details are found on the GoPro website (GoPro, n.d.-b). In the 2D Slosh Experiment, GoPro Hero10 cameras were used.

Before being integrated into the experiment, the cameras need to be set up with the GoPro Labs software and configured for the USB trigger function. The sequence of procedures used to install the GoPro Labs software, configure the cameras with USB trigger functionality, and connect the cameras to the experimental setup in this specific experiment is below.

GoPro Labs software installation steps:

1. Download the software from GoPro Labs website onto a computer (GoPro, n.d.-a).
2. Unzip and copy the folder to an empty micro-SD card.
3. Insert the micro-SD card into the camera while the camera is powered off.
4. Turn on the camera, and it will start to auto-update. Once it is updated, it will state on the video screen that the update was successful.
5. If the process does not update the camera, or shows any error, clear the micro-SD card, and retry the steps 1-4.

GoPro Control Steps:

To control the GoPro camera using the USB trigger option, a QR code (pattern) is generated from GoPro Labs software USB trigger web page (GoPro, n.d.-b). The protocol for generating the QR code to control the GoPro camera via the USB trigger is developed and maintained by GoPro.

1. The "Start Command" and "End Command" sliders are used to add any desired delays. Additional parameters can also be edited for video quality and other features based on experiment requirements. Based on these parameters, the web page (or app) generates a QR code as output.
2. Using the camera with GoPro Labs software installed and operating on battery power (disconnect the USB power if connected), scan the QR code. If the QR code is scanned successfully, the camera will then turn off, waiting for the power to be supplied at the USB port as a trigger signal.
3. Once the USB power is connected, the camera will power on based on the delay and parameters that were defined in step 2.



Figure 1. Photograph of one of the four identical cameras mounted in the flight experiment, immediately after the flight. Lens, camera, and mount are all black but note the blue "10" on top of the GoPro Hero-10 camera. Visible red and black wires passing under the mirror on the left and merging into one black cable are the DC power supply to the camera, plugged into the camera USB port that, in this view, is at the bottom of the camera. Black tape on zoom lens prevents boost-phase vibrations from affecting lens settings.

4. NOTE: If the camera is powered on manually or if the battery is disconnected, the QR code generated in Step 2 needs to be rescanned for the process to work. It might be necessary to power on the camera manually to charge the battery, and therefore, it is helpful to save the QR code for subsequent uses.

Camera Connection to the Experiment:

1. The DC power from Blue Origin's Integrated Payload Controller (IPC) is stepped down to 5 volts by a solid-state DC to DC converter and provides the external power input for the USB trigger for this experiment.
2. A DC-DC converter with 5 volts and up to 5 amps output is successfully used for two cameras operating in parallel.
3. The cameras require a power-only USB Type-C input cable for this triggering method to work. The power-only feature of the cable appears necessary to prevent the camera from seeking other signals on other wires in a fully capable USB-3 cable, which often leads to a failure to begin recording. This source of failure, or "confusion" of the cameras' operating software, was not investigated further once the power-only cables were found to be the dependable choice.

Since the time of the creation of this experiment, GoPro Labs has updated its website (GoPro, n.d.-a) to include steps like the above to download, install, and set up the GoPro Labs software in the camera. The steps listed above are those used for setting up cameras in the 2D Slosh and Rotational Slosh experiments.

A check can be done to make sure that a camera has scanned the QR and that the software is correctly installed on the GoPro camera. This was achieved by providing power to the USB port and watching for the camera to turn on and start recording. The recording is verified by checking the screen on the camera, which displays messages, or by a blinking red light on the top of the camera, which lets the user know that the recording is in progress. Recorded videos can still be accessed on the camera's display screen, through a USB cable, or by removing the micro-SD card.

The Integrated Payload Controller (IPC) provided by Blue Origin is programmed by the researcher via an XML file to execute commands based on various flight events. The IPC is thus programmed to control when to turn on DC power to the four cameras (see example, very simple, command syntax provided by Blue Origin to their customers with the IPC). Execution of the commands is ground-tested by a simulation platform provided by Blue Origin for their flight trajectory (Blue Origin Texas, 2019).

The IPC power ports provide four channels of nominally 27 volts of power with up to 2 amps of current per channel (Blue Origin Texas, 2019). The camera uses external input power and its own battery to power on the camera and subsequently uses the USB input power to continue recording. Individual cameras are found to require a peak current of 1.5 amps at 5 volts input voltage in initial tests to turn the camera on, and 0.9 amps throughout the duration of recording. A DC-DC voltage converter converts the input voltage down to 5V. A detailed view of how the cameras are connected to the power port of the IPC is shown in FIG. 2.

The cameras can be used with a USB trigger only when the battery is installed in the camera. Although the battery power is apparently not used during the recording process when the USB power is connected, battery power is required for detecting the start of the USB power that is the trigger signal to power up full camera operations and start recording. The standard battery door (cover) holds the battery firmly in place but, unfortunately, also covers up the USB input connector. Since 2D Slosh was designed, battery doors with USB pass-throughs are newly available from GoPro and performed well in a Virgin Galactic flight of Rotational Slosh, with four GoPro Hero-11 cameras. In 2D Slosh, the battery door had to be removed to allow connection to the USB port on the camera. Therefore, an anti-vibration camera mount design is required to ensure that neither the USB cable nor the battery can be dislodged during the flight. The method to prevent the

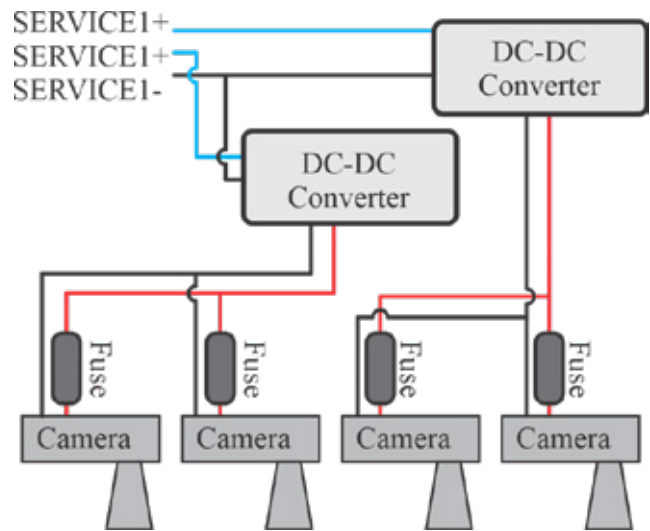


Figure 2. Schematic of the connections of one IPC power channel to the cameras. Power channel SERVICE1 of the IPC has two positive terminals and one common (ground) terminal. The fuses are 2 amps maximum to prevent excessive current draw on the IPC in case of a short-circuit camera failure. DC-DC converters are 5 volts output with maximum 5 amps current.



Figure 3. USB connection to the camera to prevent disconnection from vibrations and accelerations. Camera is mounted by two 1/4-20 screws with thread-locking adhesive from the left in this image. The block below the camera is used with a foam block (not visible) to hold the camera battery in place. The cable with right-angle plug has no room to unplug from vibrations or accelerations. An image of the test vessel with green liquid is visible in the mirror.

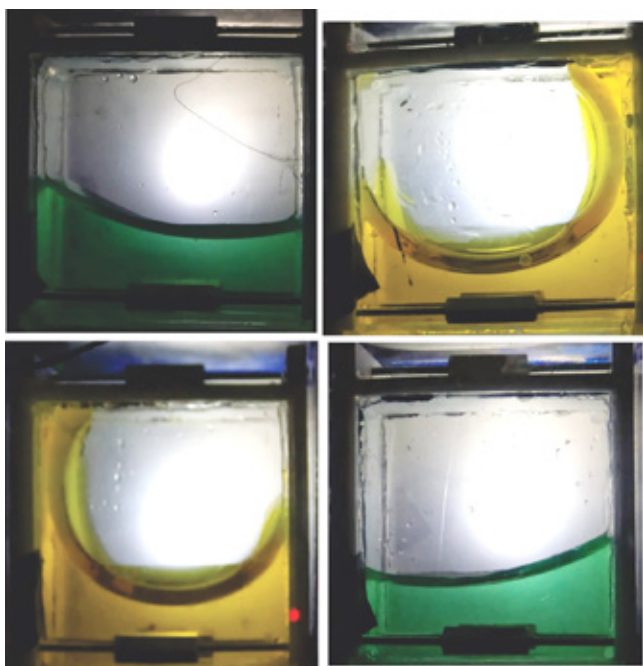


Figure 4. Images from videos acquired during zero-g spaceflight by all four USB-controlled cameras.

cable or battery from working loose from the camera for this 2D Slosh Experiment is shown in FIG. 3. The block allows the external power input cable to fit into the required space firmly and prevents the cable from working loose from vibrations or boost-phase acceleration (these accelerations are specified in the respective Payload Users Guides, for 2D Slosh (Blue Origin Texas, 2019) and for Rotational Slosh (Virgin Galactic, 2019)). Similarly, the space between the battery and the block is filled with foam which acts as a support to keep the battery in position and connected.

Mission operations added additional performance requirements to the camera triggering system. Most significantly, 2D Slosh had to be handed off to the rocket company four days before the launch in a state that required no human intervention after the hand-off. For example, there was no opportunity for any person to push camera buttons or cycle DC power even very early on the launch day. So, there is a concern about how long the camera batteries can sit waiting for the USB power to be turned on. Ground testing with the Hero-10 cameras showed that if the cameras start with fully charged batteries, then after four days of waiting, the battery charge level is in the 80 to 90% range. The variation may be due to the differing ages of various batteries or may simply be an intrinsic difference between any four such batteries. Regardless of the variation and the causes of the variation, this testing verified that the USB-based triggering system would work well after a four-day (and likely longer) wait.

Following the 2D Slosh experiment in December 2023, the Rotational Slosh experiment flew to space in Virgin Galactic's VSS Unity on June 8, 2024. Rotational Slosh implemented the USB control of four GoPro Hero-11 cameras including the new style battery door with USB cable pass-through. Control of the power to the cameras in Rotational Slosh is accomplished with an Arduino Giga actuating a solid-state relay (Sensata-Crydom model DMO063) via one digital I/O pin on the Giga. GoPro's QR code generation software was again used (GoPro. (n.d.-b).).

Results

The camera setup was successfully operated on the Blue Origin New Shepard sub-orbital spaceflight mission NS-24, also labeled P-13, on December 19, 2023 and in Virgin Galactic's "Galactic-07" mission on June 8, 2024. In 2D Slosh, all four cameras operated as planned from the time that electrical power was supplied to the experiment on the launch pad until cameras were powered off at mission end. The experiment design guaranteed that the battery and the USB input were not affected by the flight vibrations and stayed connected for the complete duration of the flight. Under control of the XML code installed on the IPC for this experiment, the cameras were also turned off and then on again near the end of the coast period of flight to ensure that the video files from the weightless period of flight were completed and closed properly and not subject to possible corruption or loss from any subsequent unplanned power loss. FIG. 4 shows images from the video recording of the 2D Slosh liquid test vessels taken by the cameras during the flight. Successful USB-controlled camera actuation results also occurred in Rotational Slosh.

Discussion

The components used in the 2D Slosh experiment are selected and tested based on the requirements of this one experiment, and other components with similar specifications could likely also function well. For example, Rotational Slosh flew a new battery door with a USB connection through the door. This door is newly available as a stock item from GoPro, and this can be used in place of the block shown in FIG. 3 with care to ensure that the USB cable will not loosen due to g-loads and vibrations. A general-use USB type-C cable has 24 pins, out of which 8 are power pins (4 ground and 4 power). It is found that the use of a power-only cable is the most dependable choice for proper camera function in this application.

The GoPro USB-based camera recording control and the camera recording function have been demonstrated to function successfully from boost to landing following a four-

day wait. The USB control feature was cycled in low g near the end of the coast period on both launches. Thus, USB control of GoPro Hero10 recording functions in a typical Blue Origin New Shepard sub-orbital mission, and Hero-11 on a Virgin Galactic sub-orbital mission can be considered TRL 9 at this point. For applicability to other camera models, see the manufacturer's web site for information as to which camera models can accommodate the USB Trigger option (GoPro. (n.d.-b)). Both of these vehicles are passenger vehicles, and thus subject experiments to relatively gentle boost and vibration accelerations, with details in both flight providers' Payload Users Guides.

Acknowledgments

The authors thank the NASA Flight Opportunity Program for their funding of the flight, some hardware, and multiple deployments for the space flights. Grant 80NSSC18K1667 is specifically acknowledged for 2D Slosh and 80NSSC20K0097 for Rotational Slosh. Purdue University provided professional machine shop time, technician time, and support of the first author as a graduate teaching assistant to aid the second author in his AAE418 "Zero-gravity Flight Experiment" class for senior undergraduates in aerospace engineering. Approximately fifty such seniors assisted in designing, building, and testing through the course of this experiment. Discussions with Blue Origin and Virgin Galactic engineering staff members were vital to creating effective experiments that are safe to fly in their remarkable vehicles.

References

- Blue Origin Texas, LLC. *New Shepard Payload User Guide*, Rev. F. Blue Origin Texas, LLC; 2019.
- Virgin Galactic. *Spaceship Two Payload User's Guide*, V24PR-D-101425. Virgin Galactic; 2019.
- GoPro. GoPro Labs. Retrieved March 22, 2024, from <https://gopro.github.io/labs/> (n.d.-a).
- GoPro. USB Power Trigger. Retrieved March 22, 2024, from <https://gopro.github.io/labs/control/usb/> (n.d.-b).
- Lokhande MM. *Two-Dimensional Suborbital Slosh Experiment*, Masters Thesis, School of Aeronautics and Astronautics, Purdue University; 2023. <https://doi.org/10.25394/PGS.22684531.v1>.